Introduction to TSI Project in KIST

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Abstract

Research in Human Computer Interface (HCI) is going towards development of an application environment able to deal with interactions of both human and computers that can be more intuitive and efficient. This can be achieved by bridging the gap between synthetic virtual environment and natural physical environment. Thus a project called Tangible Space Initiative (TSI) has been launched by KIST. TSI is subdivided into Tangible Interface (TI) which controls 3D cyber space with user's perspective, Responsive Cyber Space (RCS) which creates and controls the virtual environment and Tangible Agent (TA) which senses and acts upon the physical interface environment on behalf of any components of TSI or the user. This paper is a brief introduction to a new generation of Human Computer Interface that brings user to a new era of interaction with computers in the future.

Key words: Human Computer Interface, tangible media, virtual reality, intelligent control, human robotics, image processing, multimedia database, haptic, artificial intelligence

1. Introduction

The key purpose of the TSI project is developing a natural and intuitive Human Computer Interface taking the five sensory organs of human into account: eyes, nose, tongue, ear and skin. Today, a common user interface is a graphical user interface (GUI) without sensing the user's intention or giving the user a perceptible response. Thus, the interaction between human and computer is neither intuitive nor natural and therefore it can be cumbersome to manipulate information interactively. The word 'tangible' comes from Latin 'tangibilis' meaning 'to touch'. In dictionary it says 'perceptible by the senses especially the sense of touch' [1]. Sense of touch describes mechanical percept that human perceives through its skin. The tactile sense permits to localise and appraise touch, vibration, pain, pressure and temperature from the brain. The acceptance capacity amounts ca. one million bit per second. It is the most highly sensitive organ of a human being. This tactile sense is very important for humans because it enables them to react to danger. Therefore it enables the initiation of quick reflexes.

Taking all the sensory organs into account to develop a new interface a user can interact with computers more easily. For instance, taking the sense of touch into consideration for developing a new interface between human and computer, one can develop the interface to be more intuitive and natural for users. To make it possible a haptic device must be designed. Haptic devices enable users to get a sense of touch with computer created environment. Haptic which is the key technology to this project is a term referring to the technology of touch. Or the eyes for instance, tracking a user's sight can bring to a conclusion about what the user may interested in, and thus making computer more responsive to the user's action and intention.

TSI researches to reduce hindrances between human and computer generated virtual environment. Numerous VR interfaces have been developed but with modest success. These interfaces are still being considered as artificial and not natural to users to interact in a virtual environment.

Human Computer Interaction (HCI) is an art of information intermediation of both parties; human and computer. The technology behind HCI began with an interface which was based on keyboard, monitor and speaker. Now the interface between human and computer is progressing to more sophisticated system that takes all the human sensory organs into account, visual, aural, tactile and olfactory sense, so that human can interact with computer more naturally and intuitively. Thus, the art of HCI aims to help users to interact with machines or rather computers as intuitively as possible.

A step forward, in the technology of intelligent HCI a computer is equipped with its own intelligence, for instance, to perceive user's intent and need in order to provide the user an active respond. The intelligent HCI has developed a new kind of interface to enable the computer to recognise the user's voice, location and images in order to analyse the user's condition and intent. Based on all the sensed information from the user the computer generates and provides service to the user.

Recently the Systems Technology Division in KIST is continuously researching and developing the core technology for the intelligent HCI. It has launched a project named "Tangible Space Initiative (TSI)." This paper introduces an outline of the research and development of the core technology for intelligent HCI.

TSI treats barriers between physical interface environment and virtual environment as a malleable structure. The art of TSI is based on the concept of Tangible Space where several real objects of physical environment are integrated into a computer generated virtual environment. Tangible Space can be defined as a space that fuses physical environment with its spatial and physical limits into a computer generated environment the so called cyber space. Thus, the space creates a new kind of living environment for human which exceeds all the spatial and physical limits. The engineering of TSI includes three main components. That is, a component which can perceive human's intent within Human – Tangible Space – Real Objects to provide the human visual, aural, tactile and olfactory senses, a component that senses the real objects within the human's environment and gives those physical feedbacks and a component that generates the Tangible Space. The concept of TSI is depicted in the picture below, Fig 1.

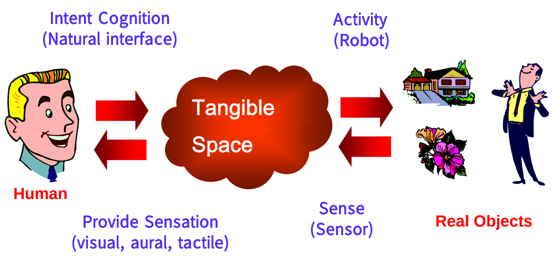

Fig 1. Concept of Tangible Space

This Paper introduces the structure of TSI aiming to integrate humans into Tangible Space. As mentioned above, TSI is subdivided into three components; Tangible Interface (TI) that manages the development of equipments needed to accomplish a linkage of human and Tangible Space, Responsive Cyber Space (RCS) which senses human's intents and needs to decide what contents to provide and Tangible Agent (TA) of which task is to develop an agent that perceives its real environment. Each component and its tasks are explained in details in the following chapters.

2. Tangible Interface

To interlink human user with Tangible Space, Tangible Interface develops the methods that can perceive user's need and appropriate equipments to provide a natural interface for users which allows them to obtain visual, aural and tactile senses.

Within the TSI project TI develops 'Stereo Based Head Tracking' technique that can perceive human's need. This technique uses three cameras to create three stereo images of human's head or rather his face from three different angles. With all the characteristics of the user's face within the recorded images it analyses his head orientation or rather his viewpoints.

The sight is one of the important and the most used sense organ. To give an effective sensation to human's sight an Immersive Large Display with high resolution is being developed. It displays four images by using a graphic processing unit from four different channels. These four images are being warped in real time to one seamless image. An image blending technique is also being developed to display the seamless warped image continuously. Besides, the image can be displayed in three-dimensional. To display the three-dimensional image, the images for right eye and left eye are displayed via two channels. To change the two-dimensional into three-dimensional image, a technique called dynamic reconfiguration is being developed to enable the alternation on line. This kind of high resolution immersive large display covers almost the whole field of vision. Thus it gives users a feeling of being immersed into the computer generated world and increases the sense of reality.

So far Virtual Reality generally provided a sense of reality only by giving users aural and visual sensations. Numerous VR interfaces have been developed to bridge the gap between real and virtual world. Though, these interfaces are still being considered as artificial and not natural to users to interact in virtual environment. To decrease the difference between virtual and real environment an interface that gives users a physical sense is needed. Hence, a haptic device which provides users a sense of touch and force feedback is being developed. Introduced with devices that give users visual and aural senses the haptic device plays an important role to create multi-modal interaction and to increase the sense of reality.

TI develops a 'wearable haptic device' to provide an interface between user and cyber space. See Fig. 2(a) and 2(b) below.

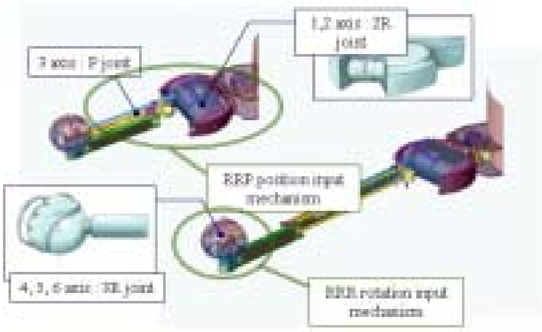

Fig. 2(a) Design of Wearable Haptic Device which can transmit and reflect user a sense of pressure, slippage and temperature onto his fingertip. To sense the quality of an object a device using a technique, which applies PDVF, is being developed. And to reflect the sensed quality of a surface to a user a texture display is being developed as shown in Fig 2(c). The mediation of the surface quality of an object through the texture display is realised by using a small pin array as shown in the picture. Texture Display can stimulate a finger vertically and horizontally. In case of a vertical stimulation a force of 0.5N is being generated by the pin arrays which are lined up in 8 rows. The pin moves up and down within a range of ±1mm. In case of a horizontal stimulation, the pin array is moved within a range of 40mm to deliver the quality of a texture surface. Furthermore, it has been planned to implement an emitter that controls temperature on the fingertip.

Fig. 2(b) Wearable Haptic Device in use

The wearable haptic device has been designed to eliminate any critical limitation in its movements and its weight so that user can easily wear it and operate it without any difficulty. It uses a brake type force reflecting actuator which can be manufactured much smaller than conventional actuators. The material of the frame is aluminium. The controller is battery driven. All together, the haptic device weighs less than 2.5kg. The wearable haptic device is worn around waist and its use is designed for right-handed. Within its motion space the handle can be driven with 2mm position accuracy and 0.2 degree angular accuracy. Its structure is designed to deliver haptic sensations to user's arm and hand. The haptic device has 6 motional degree of freedom and 3 for force feedback.

To give a force feedback to hand as well as to arm a stylus can be installed on the handle of the haptic device. By using the stylus, for instance a brush or a pen, one can feel quality of a virtual object's surface. To realise it, a hybrid surface technique has been embedded in virtual objects. As an example, an application for dentists has been developed to train their dental surgeon skills. The trainees would sense the quality of a virtual tooth's surface while he is working on it. In addition, a sound rendering has been implemented additionally to give more sense of reality.

Sound rendering is an important issue as well to merge real world in computer generated world. Ear is one of the sensory organs of human. To generate a sound exactly like in the real world while two bodies in a virtual world collide, can give user more information about the objects in the virtual world and therefore more sense of reality. Now diverse sound models for collisions of diverse materials are being developed within the TI project. It has also been scheduled to generate three-dimensional sound to give user a feeling of being immersed into the virtual world.

Another important aspect to bridge the gap between users and cyber space is to integrate a tactile sense. Fingers are one of highly sensitive part of the human body. Hence, it is useful to integrate a tactile device

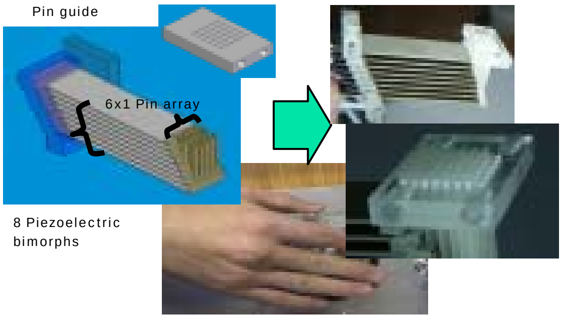

Fig. 2(c) Tactile Display Device

3. Responsive Cyber Space

A responsive cyber space is a modified and refined virtual reality. The present technological development of Virtual Reality, it has been focused mainly on generating three-dimensional images. Hence, the interaction between user and virtual environment generated by computer was monotonous and it wasn't likely to approach the real world. Like all the objects in real world contain information about their properties, conditions and qualities, objects in refined virtual reality which build the Responsive Cyber Space should also include all these information. These data are also provided to Tangible Interface where user can interact with Responsive Cyber Space. Tangible Interface provides an interface between user and Virtual Reality. This project solves the problem that Virtual Reality could not offer users to give a sense of being immersed into the virtual world. Therefore, methods and techniques are being developed to perceive and to provide users appropriate service by their needs and intents. The Responsive Cyber Space maintains the technique of realising virtual environments. Additionally, it perceives user's intent and in order to provide him an appropriate service it decides which contents to be shown by applying the techniques of Artificial Intelligence.

Problems in most cases refer to an issue requiring or asking for a solution. In order to solve a problem, human needs an exact state of the problem and all the information surrounded the problem. To sense user's needs within his environment and to provide him a possible solution is also the key feature of the Responsive Cyber Space. Of course, this should be done in non-intrusive way not to deter the user from his activity. Tangible Agent which includes elements of Artificial Intelligence takes over the sensing task. Fig. 3(a) illustrates information flow of an Agent.

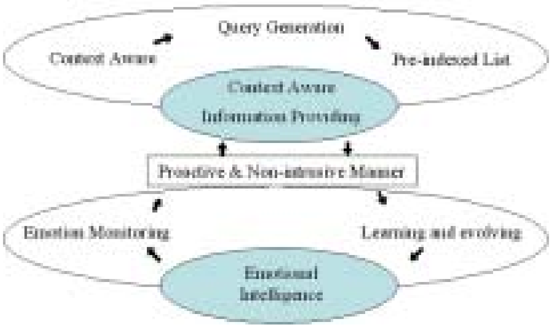

Fig. 3(a) Scheme of an Agent

An Intelligent Software Agent has been created to support mobile type interaction cyber space. It recognises user's context and then decides which contents can be appropriate to provide. To detect which contents to be provided, an A.I. based inference technique has been applied. And to recognise the state of a user, a Software Agent has been developed. With all these techniques and agents the Intelligent Software Agent has been assembled to recognise user's state in order to provide him appropriate contents to satisfy his demands.

An immersive cyber space has been created and real object images are added into the artificially created three-dimensional models in order to produce real image contents. A technique is being developed to enable the three-dimensional models to react while these are interacting with a user. To realise the reaction of the models, an image-based visual hull technique has been developed which the technique fuses the real object images and the three-dimensional virtual objects in real time. Thus a three-dimensional video avatar has been created. It can move in the cyber space in real time as shown in Fig. 3(b).

To enable one common virtual space to be shared by several users from dispersed environments a distributed interaction technique has been developed. Even though users are in different locations they can use both mobile and installable PDA within a networked cyber cinema, which can be taken as shared virtual space, to exchange information and communicate to each other. This technique is applied in an historic site scenario where users can explore and experience a cyber tour with a real pathfinder who can be seen in the virtual environment guiding the users through the historic site. The users can sense reactions of the pathfinder and explore the historic site in the virtual environment. To develop this kind of system a system based on middleware called NAVER (Networked Augmented Virtual Environment aRchitecture) kernel has been introduced. It provides a base platform for prototyping TSI applications easily. The structure of NAVER is briefly explained next.

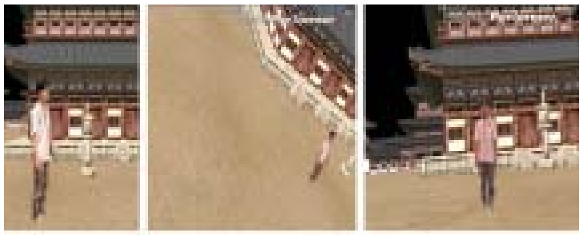

Fig. 3(b) 3-dimensional Video Avatar in Computer Graphics Environments

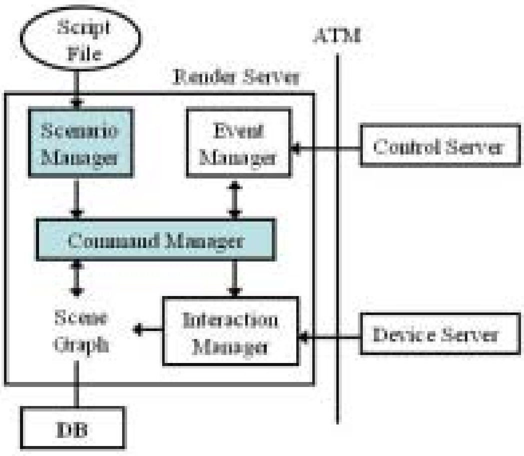

Fig. 3(c) NAVER

The structure of Naver includes Scenario Manager, Command Manager, Event Manager and Interaction Manager. Summarising a process flow, Scenario Manager validates user supplied script files in XML format and transmits verified command lists to Command Manager. Then the Command Manager executes appropriate operations such as building a scene graph, setting environmental conditions and preparing network connections according to these action lists. Also various types of operations which should be done during run-time are executed via Event Manager and Interaction Manager. There can be two types of connexion between NAVER kernel and external modules such as Control Server and Device Server. The first type is a connection between Event Manager and Control Server. We call it loosely coupled connection because their communication occurs only when required such as when spotlights are disabled promptly. The second type is a connection between Interaction Manager and Device Server. We call it tightly coupled connection because Device Server answers queries from NAVER every frame. Fig. 3(c) shows the whole structure of NAVER kernel and a connection to the external modules.

Besides, an ability to integrate several hardware devices has been developed and it is implemented into the NAVER system. And to maximize the sense of reality a module has been developed which facilitate simulations based on physical laws.

4. Tangible Agent

Tangible Agent is an interface between Responsive Cyber Space and real world. It is defined as an agent of which functions are

i. to sense the real world and augment the sensed environments to the predefined cyber space and/or give information to generate a new cyber space and

ii. to navigate the real world to sense it and/or interact with real world to do the user specified job or gather tactile information.

The definition of TA is similar to that of Autonomous Agent which is defined as a system situated within and a part of an environment that senses that environment and acts on it, over time, in pursuit of its own agenda and so as to affect what it senses in the future [4]. Typical characteristics of Autonomous Agent are

i. to perceive and interpret sensor data

ii. to reflect events in their environment and

iii. to take actions to achieve given goals[4].

From this, the reactiveness, that is, sensing and acting capability could be considered as the same characteristics between two agents. The difference is however that since TA is one of component technology for Tangible Space of which goal is seamless integration between cyberspace and real world, TA should provide its own reactive function while satisfying for users with seamless integration. That is, the most important function for the TA is how to enable users to feel seamless sensation for the cyber space which is augmented and interacted with the real world by agents.

There are two major technologies for TA to do its role such as reality sensing and information augmentation and intelligent real world navigator with action capability. TA contains ‘Intelligent Action Navigation’, ‘Reality Sensing’ and ‘Sensor Network based Location Awareness’.

The Intelligent Action Navigation provides a Robotic Agent that can satisfy users’ needs. A so called Physical Avatar is being designed to sense and to provide users with information they require. The user can communicate with the physical avatar as naturally as he communicates with human. It can move autonomously through the environment where user is also located. For that, a technique called dependable navigation is being applied. Also, a self-location determination technique has been applied to trace its own location.

The Reality Sensing is sort of a ubiquitous camera network. It recognises user’s location and his identity through his ID tag. It also senses the whole environment where the user is located. An automatic restoration technique is applied to perceive the surrounded environment; a three-dimensional scanned data, created by a laser scanner, is being used to generate three-dimensional models through data registration process.

The Sensor Network based Location Awareness develops an indoor GPS system depicted in the picture below, Fig. 4. It should provide information about user’s location and possibly his intention to clients. The indoor GPS system consists of beacons and master modules. The beacons which are installed on the ceiling emit ultra sound; a master module calculates its distance, with help of the ultra sound signalled by three beacons, to each beacon and transmits its location, for instance, to physical avatar to inform the location of the master module which can be attached to a user. The master module is attached to physical avatar as well to be aware of his location. All the active beacons are equipped with small motors to direct and to aim their signals efficiently and precisely to the master modules.

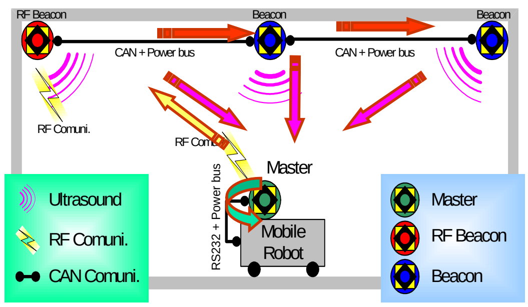

Fig. 4 Indoor GPS Schematic Diagram

Besides a technique that tracks multi-object images using “colour clustering” method, which is insensitive to illumination, is being developed to track the position of a user. This technique is applied to several camera sensor networks within a fixed space to perceive user’s location.

5. Conclusion

This paper has introduced the recent research and development of the “Tangible Space Initiative” project that has been carried out by the Systems Technology Division in Korea Institute of Science and Technology.

TSI treats the barrier between the physical interface environment and the virtual environment as a malleable structure. In other words, TSI fuses both the physical and virtual environments to Tangible Space and links humans to it. To realise it, TSI is subdivided into three components: Tangible Interface (TI), Responsive Cyber Space (RCS) and Tangible Agent (TA). TI, which deals with developments of methods and devices, enables users to manipulate virtual objects it and synchronises the real and the virtual environment. RCS is responsible for developing methods of how to recognise users' needs and intents in order to provide them appropriate contents and it comprises all the real and virtual objects included in a virtual environment and its behaviours. And TA creates an Agent that senses real environment, user's view and his intention in order to response to his expectations and to provide him desired information.

These three components of TSI are the elements of Intelligent HCI. Furthermore, these components are the basic elements to realise Tangible Space. To assimilate the three components into Tangible Space a Demo Room has been created as an example for demonstration. In the Demo Room one can explore a historical site projected onto the large display. On demand, a physical avatar will guide user through the historical site and the user can enjoy the contents provided by the Agent who perceives his intent, a tailor-made tour that suits the user's taste. Moreover, the user can experience a sense of reality while using the wearable haptic device to open and to close a door in the virtual historical site. The user can not only open or close the door but he can also try to paint virtual objects using the haptic device as well.

Besides, in order to explore the historical site from separate locations at the same time an immersive Tangible Space has been created that integrates all the distributed Virtual Reality environments to enable users to interact with each other. The users simply use PDA to experience this kind of interaction.

In the future research plan, Tangible Interface will be developed in three stages such as conversational interface, responsive interface and intelligent interface. Thus, the development of the interface between human and computer is concentrated on perceiving human's intent and providing him aural, visual and tactile sense more efficiently. For Responsive Cyber Space a cyber platform, which focuses on integrating physical and virtual environment into Tangible Space, is going to be created in three phases; constructional, adaptive and autonomic cyber platforms. And Tangible Agent will be developed as follows; command based, mission based and cognitive based agents.

The art of Tangible Space is a part of Human Computer Interaction where human science is essential to understand human's perspective of handling machines etc. All the research and developments of the TSI project will take the human science into account.

The aim of this project, with help of the development of computer hardware and software, is to develop the interaction methods and techniques in advance, while the living space of humans changes, to foresee and to synchronise the methods and techniques to the changes. It is expected that the results of this project will be applied in every field of human life in the future.

Acknowledgement

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